tinued large export of crude unrefined ores and metal products and the corresponding imports of refined and manufactured metal products still point to opportunities for the development of metallurgical industries as well as industries for the treatment, refinement and manufacture of non-metallic products.

Owing to our contiguity, our mutual relations, our essential unity of race and general characteristics and identity of language, we can but wish our northern brethren success in the development of their rich mineral country.

AFTER the preceding remarks relating to this subject were in type, but not yet published, a recent "Preliminary Report on the Mineral Production of Canada during the Calendar Year 1912, prepared by John McLeish, B.A.," has been received, although the data are subject to revision for a final report.

The total mineral production is stated for 1912 to be $133,127,489, or $29,906,495 over that of the preceding year, and $26,303,866 over that of 1910, heretofore the banner year. So notable an increase points towards a more general prosperity. The relative rank in production of the different provinces remains as in 1911, except that Alberta and Quebec have changed places, the product of the former being valued at $12,110,960 and the latter $11,675,682. For Ontario the value is $51,023,134, for British Columbia $29,555,323, and for Nova Scotia $18,843,324.

Of the value of the total production, as is quite general, the non-metallic is the greater or $71,949,500, while the metallic is $61,177,989.

The value of some of the more important Canadian mineral products are given in the table below.

	Value
Coal	$36,349,299
Silver	19,425,656
Pig iron	14,550,999
Nickel	13,452,463
Copper	12,709,311
Gold	12,559,443
Clay products	9,343,321
Cement	9,083,216
Stone	4,675,851
Asbestos and asbestic	2,979,384
Natural gas	2,311,126
Lime	1,717,771
Lead	1,597,554
Gypsum	1,320,883

The production of petroleum has been steadily falling off for the past five years, the value for 1912 being $345,050. The values of the production of copper, silver and gold have increased, especially in the case of gold from the Porcupine District. In brief it may be said that except for petroleum, the values of all the Canadian productions have increased since 1911.

For 1912 the value of the exports of mine products and of the manufactures of mine products has been $68,585,286, the chief ones being in order of value: silver, gold, copper, coal, nickel, asbestos, automobiles and aluminum.

By comparing the reports of previous years the mineral industries of Canada present, on the whole, very encouraging features for our northern neighbors and prove that a rapid development is taking place.

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SPECIAL ARTICLES

ARTIFICIAL PARTHENOGENESIS IN FUCUS

THE occurrence of natural parthenogenesis or the development of the gametes without fertilization has been reported for several forms among the Phæophyceæ. Berthold and Oltmanns observed it in *Ectocarpus siliculosus,* which possesses, besides zoospores, gametes of two sizes. Both male and female gametes even in the same culture under certain conditions develop parthenogenetically. The question has been raised whether the so-called zoospores are not parthenogenetic gametes. Sauvageau observed that in *Giffordia secunda* antheridia were produced in greater numbers in July, but that none were formed in August or later, while numerous oogonia appeared at this season, many of whose

eggs cleaved very slowly without fertilization. The older observations of Thuret and of Crouan that the eggs of *Cutleria* develop without fertilization have been confirmed by Church, who reports that on the English coast *Cutleria multifida* develops mostly parthenogenetically, female plants being hard to find in August, and that scarcely any occur in the latter part of the season, the eggs developing without fertilization. As was previously observed by Thuret and Bornet, Williams has more recently found that the unfertilized eggs of *Dictyota* and of *Haliseris* segment a few times and then die.

It is evident that the Phæophyceæ show a strong tendency toward parthenogenetic development and that natural parthenogenesis may play an important part in the life history of several species. None of the Fucaceæ, however, have been reported as being able to develop without fertilization, although Thuret mentions that unfertilized eggs of *Fucus* kept for several days become pear-shaped and that a cellulose wall is sometimes present. Thuret's observations have not been supported by Farmer and Williams, who have never been able to observe cellulose walls around unfertilized eggs. My own observations are in harmony with those of Farmer and Williams. While working at the Marine Bioogical Laboratory at Woods Hole, the past summer, it seemed worth while to apply to *Fucus* eggs some of the well-known experimental methods used by Loeb, Winkler, Delage, Lillie and others, whereby unfertilized eggs of certain invertebrates have been made to segment under the influence of artificial physical and chemical stimuli.

Fucus vesiculosus, a diœcious species, occurs near the shores between tide marks at Woods Hole, and plants, both in the vegetative and reproductive conditions, are usually abundant. The spermatozoids and oospheres are usually discharged sparingly during ebb tide and abundantly during flood tide. Plants were collected during ebb tide, the distal portions removed and placed in dishes on ice over night. Care was taken that the conceptacles bearing eggs and sperms were kept separate. When it was desired to obtain the eggs and sperms, dishes containing conceptacles were filled with fresh sea-water, or after first exposing the conceptacles to a hypotonic sea-water, when eggs and sperms were discharged in large numbers. The freshly extruded eggs drop to the bottom of the dishes and can be taken up with a pipette and transferred to watch glasses for experiment. After a short time the eggs show a tendency to adhere very firmly to the bottom of the watch glasses so that fluids can easily be poured off and others added without losing the eggs.

The process of fertilization in *Fucus* has often been studied, and the details of development were especially studied by Thuret and later by Oltmanns. If the mature eggs and sperms are mixed together in the same dish in sea-water, the sperms collect in great numbers about the egg, and attaching themselves to the periphery cause the eggs to rotate rapidly by lashing the water with the cilia. Soon the eggs lose the power of attracting the sperms. They cease their rotation and settle down. Such eggs are fertilized. Farmer and Williams have shown that within five minutes after mixing the sexual cells the sperms have entered many eggs and within ten minutes the sexual nuclei fuse. Soon after fertilization a delicate membrane or cell wall is formed about the periphery of the oospore. As noted by Farmer and Williams, the character of the cytoplasm changes markedly, tending to assume a definitely radiating character, the lines radiating from the nucleus as a center. The oospores rest for about twenty-four hours, during which time there is a rapid increase in the thickness of the cell-wall and a further change occurs in the structure of the cytoplasm like those described by Farmer and Williams. At the periphery of the fertilized egg, just below the wall, the cytoplasm shows a definite alveolar structure.

After some time many of the oospores assume a pear-shaped form and by the next day all have divided. The first division, as has been observed by Rosenvinge and others, is at

right angles to the direction of the light. In the main my observations on the physiology of germination are in accord with those of Farmer and Williams. In watch glasses, placed on a laboratory table, the first division is usually at right angles to the bottom of the watch glass and at right angles to the direction of the light. Abnormalities in cleavage and development as described by Küster were sometimes, but seldom, observed. The cell away from the light is the rhizoidal cell, while from the other cell the young thallus develops. The subsequent cell divisions and growth of the plantlets in watch glasses follow the descriptions of Thuret and of Oltmanns and need no special mention. In watch glasses placed in larger dishes of sea-water, young plants of about 25 cells were grown in the laboratory. No attempt was made to rear the plants beyond these young stages.

In plants used to induce cell division by artificial means great care was taken to prevent contamination by sperms. The female plants were carefully washed with fresh water to kill any sperms which might adhere to them. None of the eggs obtained from such sterilized plants ever developed in the numerous controls, which were run in connection with the experiments, showing beyond a doubt that the female plants treated were absolutely sterile.

Loeb has shown that, when unfertilized eggs of the sea-urchin are placed for one and one-half to two minutes in a mixture of 50 c.c. of sea-water + 3 c.c. of 0.1 *m* acetic, butyric or other fatty acid and then transferred to normal sea-water, a fertilization membrane is formed. This method was applied to unfertilized *Fucus* eggs. In experimenting with the eggs those used at any one time were always divided into three lots. One lot was used as a control, another was fertilized and the third was treated with the solution. If a single egg in the control formed a cell-wall, which seldom happened, the three lots were discarded. In case the eggs were treated with acetic or butyric acid, as above described, a large number of them formed in about ten minutes a membrane or cell-wall which was exactly similar to the one formed about normally fertilized eggs. By plasmolyzing the eggs the membrane is readily seen. Eggs not treated with a solution or not fertilized undergo cytolysis and degenerate. In any case many of the eggs failed to develop, but about one fourth as many formed membranes under the influence of the solutions as were formed about fertilized eggs. After the formation of the membranes if the eggs are placed in hypertonic sea-water, 8 c.c.–10 c.c. of 2.5 *m* NaCl or KCl + 50 c.c., sea-water for 30 minutes and are then brought back into normal sea-water, development continues. Nearly all of the eggs which have formed a membrane become pear-shaped, showing a rhizoidal papilla, and by next morning have cleaved. The rhizoidal cell is cut off and one or more cleavages have taken place in the other portion of the sporeling. If the cultures are properly aerated, sporelings develop resembling in every respect those grown from fertilized eggs. In place of sea-water containing a fatty acid, solutions of various other cytolytic substances were used, but none stimulated membrane formation or development as well as the acids.

With regard to the first formation of the cell-wall over the surface of isolated masses of plant protoplasm, it is usually attributed to a process of secretion by the outer layer. That the process is a rapid one is shown by the fact that in *Fucus* eggs a cell-wall is formed in ten minutes after the entrance of the sperm. Cell-wall formation may also be artificially induced, as shown above, by various substances. In some cases a cell-wall may appear under certain conditions on the surface of plasmolysed protoplasts in fifteen minutes, as has been shown by Klebs, Palla and others, while in other cases hours are required for wall formation. It would appear that the action of the acids in inducing a cell-wall to be formed about the unfertilized *Fucus* eggs is similar to the action which calls forth membrane formation in the animal egg. Considerable evidence exists indicating that the essential con-

dition for the formation of the fertilization membrane in many animal eggs is an increased permeability of the plasma membrane for substances which pass out and harden in contact with the sea-water. The rôle of the acid, etc., in membrane formation is held by many to be the increasing of the permeability of the plasma membrane of the egg.

That the first effect of the sperm of the Fucaceæ upon the egg is to cause cell-wall formation, conditioned as it seems to me by a momentarily increased permeability of the plasma membrane just as in certain animal eggs, is apparent from the observations of several investigators. Farmer and Williams furnish remarkable evidence showing that the entrance of the sperm supplies the stimulus which leads to the formation of the cell-wall in *Halidrys*. In this form pieces of the oospheres are sometimes pinched off during extrusion. These observers note that such pieces sometimes attract the sperms and become fertilized, surrounding themselves with a cell-wall in the normal way. The cases of merogony induced by Winkler in *Cystosira barbata* may, I think, be explained by assuming that the sperms increase the permeability of the non-nucleated fragments, as well as being the underlying cause of further development. In the normally fertilized eggs of *Halidrys* Farmer and Williams note that the entrance of the sperm causes the eggs to swell and become more transparent. In some cases movements of vacuoles are discernible and the nucleus may change its position. They conclude that these alterations ensue as a definite result of the stimulus given by the sperm. The fertilized egg becomes covered by conical projections, from each of which a fine thread projects, consisting of a series of droplets. After 3–5 minutes the fertilized egg resumes its spherical shape and decreases in diameter. They also observed that the sperms were repelled from fertilized eggs and conclude that this is due to the excretion of some substance which exerts a negative chemotactic and injurious effect on the sperms. Such eggs at once become invested in cell-walls, while others not exhibiting these phenomena after a time degenerate.

The results of my experiments, in which cell-wall formation and subsequent development were induced in unfertilized eggs of *Fucus*, and the data mentioned above, seem to show that the first effect produced by the sperm upon the egg is purely superficial, causing an increase in the permeability of the plasma membrane. These conclusions are in harmony with those of certain animal physiologists. Therefore, theoretical considerations as to the causes of the change in permeability and the stimulus to further development need not be discussed here.

As yet I have been unable to investigate the nuclear behavior of the parthenogenetic plants of *Fucus*. Farmer and Williams, agreeing with Strasburger, hold that the *Fucus* plant contains the diploid number of chromosomes and that the reduction to the haploid number occurs during the first division in the oogone and in the antherid. Since the eggs of these plants induced to develop without fertilization contain the haploid number of chromosomes, one can assume, unless a regenerative doubling in their chromosome number occurs, that the nuclei of the sporelings contain the haploid number. It would be of interest to grow these parthenogenetic sporelings to sexual maturity and to investigate the chromosome behavior especially during oogenesis and spermatogenesis. Hoyt has carried sporelings of *Dictyota* to maturity by sowing the spores on oyster shells, and transferring these to the open water after the sporelings had become firmly attached. Lewis had used similar methods successfully with the sporelings of certain Florideæ. Fertilized eggs of *Fucus* when allowed to settle down on oyster shells in the bottom of dishes become firmly attached and produce the sporelings. *Fucus* eggs induced to develop by artificial stimuli also produce sporelings on oyster shells. For lack of time I was unable to transfer them to the open water, but the method is suggestive.

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